Towards Data Driven University Departmental Strategies

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ABSTRACT

The industrial gravitation towards data driven improvement methods is absent from university departmental strategies. In order to apply a systems approach to department improvement, data driven quality metrics (system outputs) and controllable system inputs must be found and correlated. This paper explores these correlations in the context of highly ranked industrial and manufacturing engineering departments. Variations in the way each department operates are discussed in terms of their correlation to both currently used quality metrics and proposed data driven metrics. The conclusion is reached that a Pareto surface exists constraining the department research expenditures and peer determined U.S. News and World Report department ranking. This balance is controlled primarily by the proportion of theoretical and practical faculty members for the respective field.

I. Introduction

Several measures of university department quality exist for the purpose of helping deans, chairs and faculty to improve their departments as well as helping student to choose their universities of study. There is no definitive way of determining what makes an institution "good." University administrators suggest that recruiting is the key: the quality (in terms of intellectual capacity) of both students and faculty is the best indication of institution quality (Anderson 2004). Additional indications of institution quality, like the economic influence of the intuition, are impossible to measure directly and difficult to estimate using surrogate measures.

In general, department quality is judged by economic measures, like the amount federal research grants the department is able to obtain; and measures of peer reputation, like the U.S. News and World Report (USN&WR) rankings (Rouse and Garcia 2004). These rankings are based on the intellectual clout of the department in question and reflect its ability to, among other things, create new knowledge (primarily in the form of publications or development).

When addressing departmental improvement from a systems approach it makes sense to consider the industrial tendency to utilize data driven methods. To build a data driven improvement strategy for university department improvement, measurable system outputs (quality metrics) must be identified and system inputs (strategy decisions) must be mathematically related to the outputs.

The nature of the exploration of university department strategies is discussed in the context of research performed by Radford et al. in Section II: Problem Context. A description of the currently used institutional quality metrics (Section III: Practical Metrics) leads to a definition of proposed new quality metrics in Section IV: Towards Ideal Metrics. The system inputs and their correlations to the previously discussed quality metrics are addressed in Section V: Candidate Strategies. Finally, in Section VI: Conclusions and Future Work, ultimate recommendations and suggestions are made for continuing research towards ideal university departmental strategies.

II. Problem Context

In the context of hospital cardiology departments, Radford et al. investigated a more "valid" measure of success than the USN&WR rankings. This "high-fidelity" quality metric was "adjusted mortality rates." They concluded that the higher ranked hospitals did, in general, did have lower mortalities rates; therefore, demonstrating a relationship between the high fidelity measure (mortality) and the ranking—a surrogate quality measure. However, they also concluded that the differences could almost entirely be attributed to 'small' decisions that were made, e.g., the use of beta blockers, aspirin and the lack of use of reperfusion therapy. The associated surrogate measure (USN&WR ranking) is not based on these easily controllable variables but rather intermediate variables that are not directly controlled by administrators but more easily measured (e.g., number of nurses, or research funding).

The goal of data driven departmental strategy is to find the decision options that improve the high-fidelity measures, making use of the surrogate measures such as ranking when helpful. More formally, following variables are defined:

X_n = policy (or resource contraint) variable,
$\tilde{y}_n$ = intermediate variable (used by US News to make ranking),
$\bar{y}$ = surrogate measure (US News score/ranking) and
y_1 = true measure (high fidelity data).

X_n are the decision variables that constitute a "strategy." For example, " x_1 = prescribe beta blockers" or " x_2 = do not prescribe beta blockers" are options. The use of x_1 or x_2 have respective influence on the high fidelity quality measure: mortality (y_1). The goal for an ideal data driven model of university departmental quality is to find X_n's, or easily controllable variables, that have a true impact on appropriate high fidelity quality metrics (y_1's).

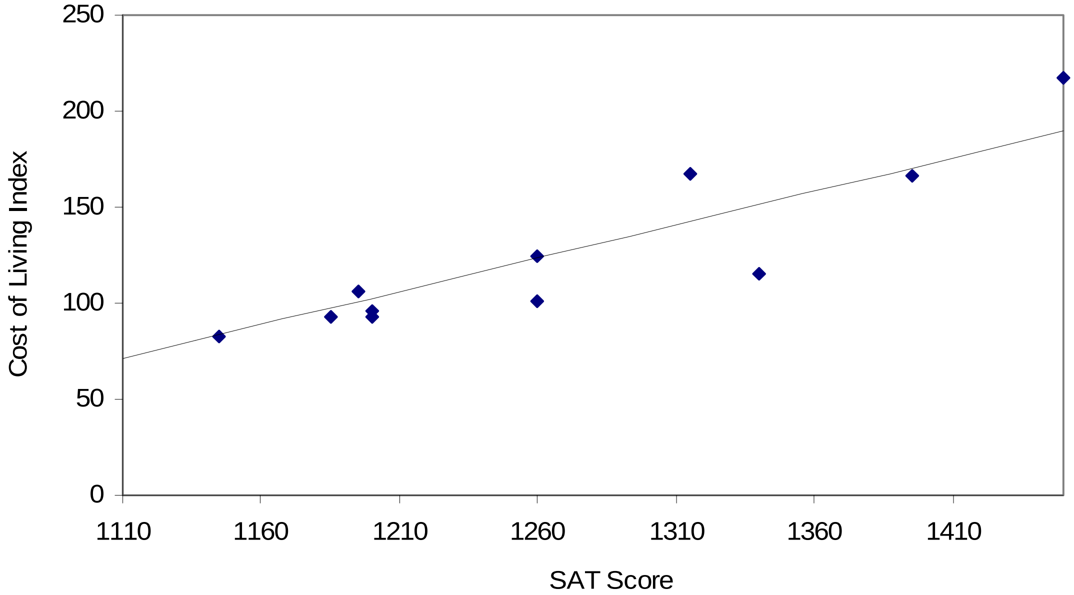
III. Practical Metrics

There are several opinions on what quality means in the context of an educational institution. For example, in secondary and primary education a method of value added assessment is used. In this context, individuals' standardized test scores are tracked year to year. Progress, or added-value, is the measurable metric (Callender 2004). However, university administrators judge quality as a function of the students and faculty: to improve your department, you must recruit better students and faculty. This is, however, a difficult measure to assess. Departments typically use more easily accessible metrics (or system outputs) such as national department rankings like those published annually by U.S. News & World Report (USN&WR).

The USN&WR rankings and others like it are subjectively based. They are based on peer (deans, chairs and faculty) judgments (Rouse and Garcia). Additionally, the university-wide rankings reflect a multicollinearity (correlation of inputs) correlating the SAT (Scholastic Achievement Test) score[1] with cost of living (for the city or region in which the school is located[2]), (see figure 1).

[1] Arithmetic mean of 25th- and 75th-percentile SAT scores (or ACT scores converted to SAT using an equivalency table published by the College Board)
[2] Cost of living data taken from Cass Recruitment Media and based on real estate value indexes published by the U.S. Department of Housing and Urban Development

Figure 1 SAT Score and Cost of Living Index Correlation



For whatever reason, students with better SAT scores tend to attend schools that are in the more expensive parts of the country. SAT score is used as an input in the university-wide rankings (which arguably affect department rankings). This correlation means that schools that are located in the most expensive cities may have unfairly inflated rankings.

Besides the USN&WR rankings, other output metrics used by university department stakeholders include: grant money (both amount of federal subsidized grants received and the total amount of research expenditures), the number of students and the national level exposure/accomplishments (often estimated by a count of national level publications).

IV. Towards Ideal Metrics

All practical metrics primarily address a department's peer reputation: how well it compares to its counterparts in terms of its ability to create knowledge. There is a need for a metric that addresses student needs and/or quality in terms of a department's ability to educate.

In primary and secondary education, a value added measure has been used for barometer of educational quality for some time. As Jamie Callender (Ohio State Representative 62nd House District) explains, "[the] challenge for schools is how to add 'value' to ensure that each student received at least one year of growth for one year of schooling." Primary and secondary schools use a measure of individual (for each student) changes in standardized testing scores from year to year to calculate this. For example, if a student moves from an 85th percentile score in the fourth grade to a 90th percentile in the fifth, he has theoretically achieved more than one year's growth during the fifth grade (an indication of his school's ability to educate).

This philosophy was extended into the world of undergraduate education[3] to create the proposed value added index. However, rather than using standardized testing scores to assign a value at time of graduation, an analogous economic measure was used: pseudo-average starting salary[4]. The associated value at time of high school graduation was determined using an average of the 25th and 75th SAT percentiles for students admitted to each university.

The proposed metric, value added index (VAI), was determined by running a joint regression mapping SAT score and cost of living index (for the city or region in which the school is located) onto the pseudo-average starting salary and analyzing the residuals. Assuming that students with equal SAT scores are economically "worth" the same (immediately after high school graduation), these residuals represent the overachievements or shortcomings (in terms of value added to students) of each department.

A sample of highly regarded industrial and manufacturing engineering departments was selected based on the sample used by Rouse in the Georgia Institute of Technology Industrial Engineering Department benchmarking study.

Table 1
Value Added Index

Department	**Residual (VAI)**
Northwestern	-$4,240
VA Tech	-$3,456
Penn State	-$1,748
NC State	-$1,406
Michigan	-$1,022
Ohio State	$655
Texas A&M	$798
Stanford	$1,609
Berkley	$1,644
Wisconsin	$2,290
Purdue	$2,346
GA Tech	$2,528

The proposed VAI metric was built on the assumption that education does directly add economic value. It has been suggested by Akst (2004) that schools do not add value; students at elite universities make more money because they possessed the skills necessary (intelligence included) to be accepted to these universities and later get high-

[3] Undergraduate education was used because of the increased availability of statistical data for undergraduates. However, a strong corollary can be demonstrated between undergraduate and graduate department quality using the respective U.S. News and World Report rankings.

[4] Based on on-hand starting salary data collected from departments respective exit surveys. If only mean, choose mean. Pseudo Average Starting Salary (PASS) calculated using following logic:

If only median is available, choose median.

If both mean and median are available, and lower value is within 5% of higher value, report median.

Else, report arithmetic mean of the mean and median.

paying jobs. However, the presence of these residuals indicates that other factors are at work. The highly ranked schools do accept the students with higher SAT scores (the best indication of "the skills necessary…"), however they do not necessarily make more money.

Because this proposed metric is calculated using correlated inputs (SAT score and cost of living index), the same multicollinearity discussed above exists. However, this may be able to be ignored because, in the case of the VAI, the uncertain causality issue affects the regression model, but not the residual. More research will be necessary to determine the effects of using such a metric.

V. Candidate Strategies

Once the appropriate metrics (system outputs) have been determined, in order to facilitate department improvement, it is necessary to understand what department strategies (or system inputs) are controllable and how their settings influence the associated metrics. It has been suggested that mature industries show a convergence of technology often coined "industry polarization". However, a surface-level inspection of university departments indicates otherwise. Observationally, departments differ in their application of three strategies:

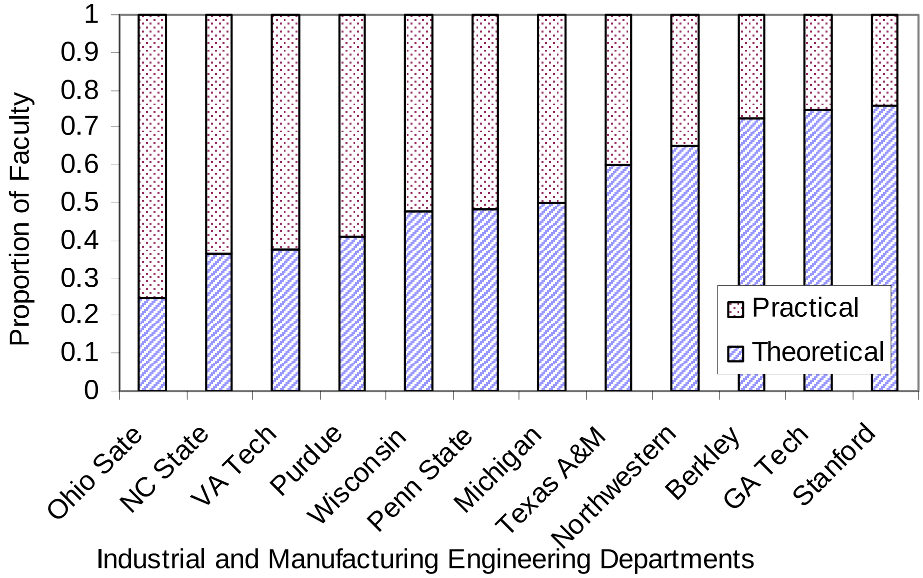
- Type 1 Inputs – Faculty Composition Balance:
  Distribution of faculty between theoretical and practical concentrations
- Type 2 Inputs – Departmental Emphases:
  Management of faculty priorities through (among other means) conditions of promotion and tenure
- Type 3 Inputs – Curricula Distribution:
  Distribution of required curriculum among field concentrations

Type 1 Inputs – Faculty Composition Balance

To gauge each sample industrial and manufacturing engineering department's faculty composition, a method of faculty composition profiling was used. This method classified each faculty member[5] into one of five intuitively determined concentrations: (1) ergonomics, (2) cognitive science, (3) operations research, (4) manufacturing and (5) engineering economics and ethics. Each of these groups was either classified as a theoretical or practical concentration. Industrial and manufacturing engineering departments are unique because of their diversity. Faculty members in these departments participate in both excessively theoretical research (operations research, etc.) and research that is industry driven (manufacturing, etc.). A similar distinction is made in the realm of civil engineering departments (Koehn 2001) where hydrology and geotechnical engineering are compared to the more traditional structural engineering concentration. For the industrial and manufacturing engineering sample, theoretical concentrations included: operations research, engineering economics and ethics; and practical concentrations included: ergonomics, cognitive science and manufacturing.

[5] Faculty bios/profiles were obtained from each department's respective website. Only current faculty (excluding those with professor emeritus status) were included.

Figure 2 Results of Faculty Composition Profiling Among Sample Industrial and Manufacturing Engineering Departments



An attempt was made to relate the department composition (as determined by faculty composition profiling) to the determined metrics of departmental quality. These correlations demonstrate the consequences of the aforementioned balance between theoretical and practical department fields. For each measure, the theoretical/practical balance has an effect (see figures 3 and 4).

Figure 3 Sample Industrial and Manufacturing Engineering Department Faculty Composition Correlation

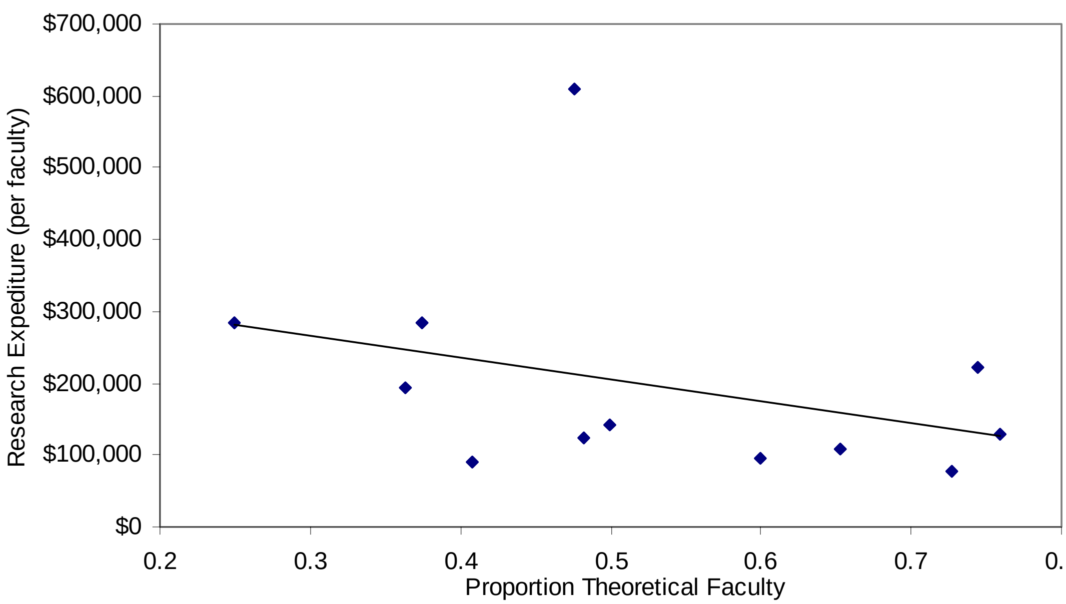
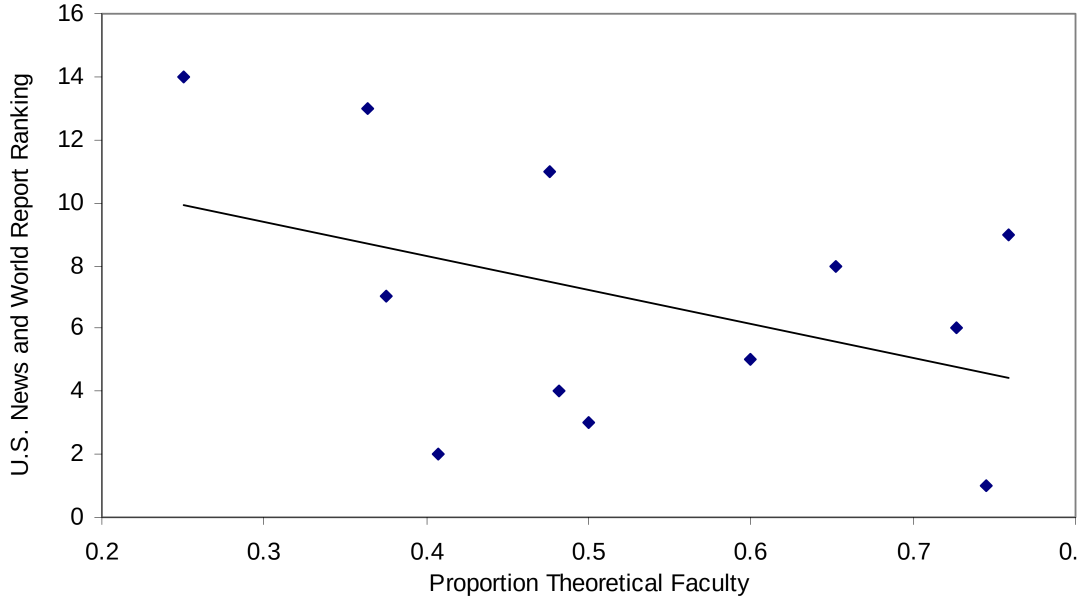
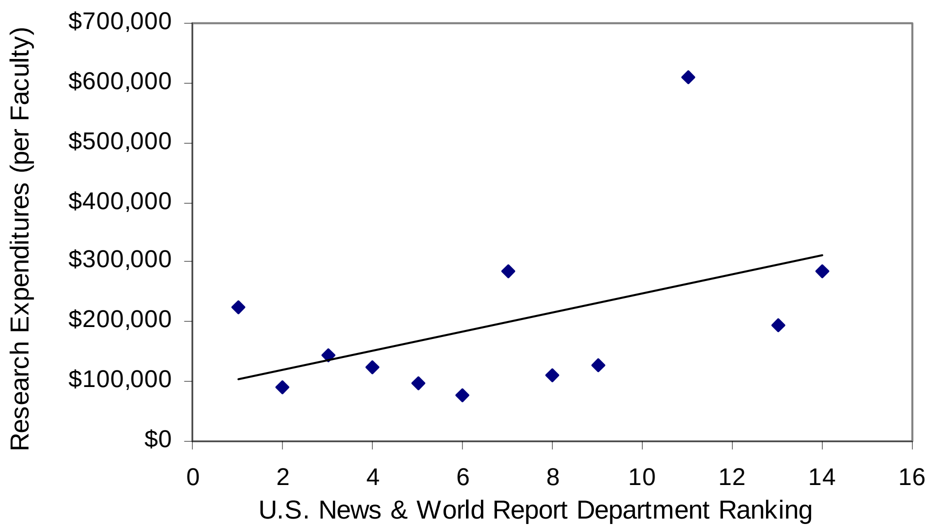


Figure 4 Sample Industrial and Manufacturing Engineering Department Faculty Composition Correlation



In general, as the proportion of theoretical faculty increases (and likewise the proportion of practical faculty decreases), the research expenditures (per faculty member) worsen and the USN&WR department rankings improve. As figure 5 indicates, a compromise must be made between research expenditures (per faculty) and USN&WR department ranking. This compromise is controlled by the respective proportions of theoretical and practical faculty.

Figure 5 Sample Industrial and Manufacturing Engineering Department Research Ranking Pareto Surface



It must be considered that, as a variable, hiring faculty is expensive to manipulate. However, using the known relationship between faculty composition and each of the quality metrics, it may be possible to use policy (i.e. encouraging interaction between certain concentrations) to influence metrics without making expensive investments in faculty.

Type 2 Inputs – Departmental Emphases

A preliminary departmental emphases survey was distributed to the sample of industrial and manufacturing engineering departments. This survey forced department representatives to rank the departments' educational and promotional priorities. (See figure 6 for sample results).

Figure 6 Industrial and Manufacturing Engineering Departmental Emphases Survey Sample Results

In criteria for promotion and tenure, rank categories according to what your department's priorities (1 is top; 5 is lowest)

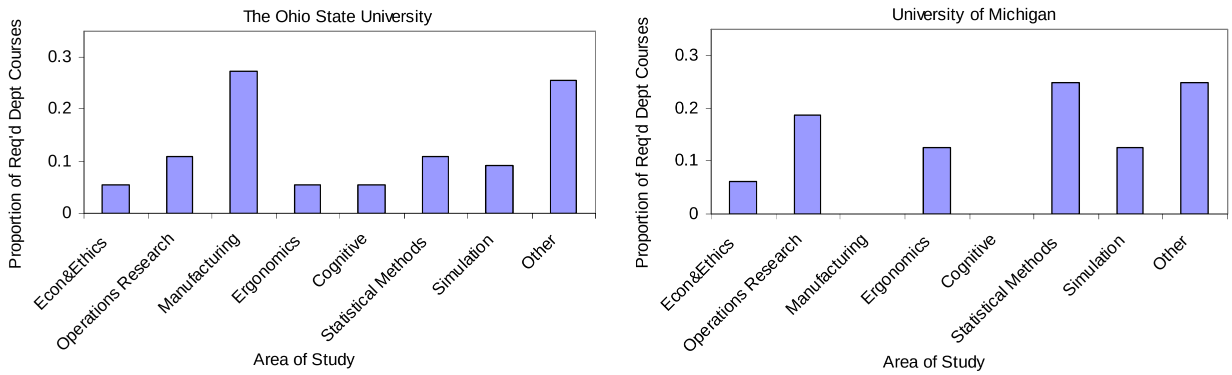
	Penn State	Purdue	Wisc	VA Tech	Ohio State
No. of federal grants	2	3	**(1)**	2	2
grad student job placement	3	5	3	5	5
subjectively assessed publication quality	**(1)**	4	5	3	4
teaching ability	5	2	4	4	3
No. of top tier publications	4	**(1)**	2	**(1)**	**(1)**

Of the five departments that responded, three different criteria were chosen as top priority. Unfortunately, there was not enough of a response to definitively tie departmental emphases to any quality metrics. However, because of the variation in priorities among the group, departmental emphases show potential for being a useful input to influence departmental quality metrics.

Type 3 Inputs – Curricula Distribution

Similar to the faculty composition balance inputs, curricula distribution focuses on the distribution of credit hours among required courses in the undergraduate curriculum in each department. It could be argued that the curriculum may not necessarily affect quality measures including a student's competitiveness in the job market. However, as figure 7 indicates, the variation between different departments' required curricula make it an important input to study for potential ties to quality metrics.

Figure 7 Sample curricula distributions for Ohio State and Michigan Industrial and Manufacturing Engineering Programs



This preliminary curricula study only focused on required department courses, the difference between prerequisites and non-departmental required courses were not considered. In addition to studying the effect of the curriculum composition on department quality, the effect of teaching required prerequisite courses either within the department or in other departments should be explored. For example, does is matter whether statistics is taught through the math department or as a specialized engineering department course?

VI. Conclusions and Future Work

Currently used practical university department quality metrics exclude measures which reflect the institutions ability to educate or the needs of students. Some metrics, including the USN&WR department rankings, are peer reputation based and therefore pander to other departments rather than students. The balance of theoretical and practical faculty correlates with the balance between departmental rankings and available research expenditures. By creating new data driven quality metrics (like the proposed VAI), department improvements can be made without being constrained to the ranking/research funding Pareto surface. Future work will include justifying a value added measure and/or creating other data driven quality metrics.

The proportion of theoretical and practical faculty members has little correlation with the proposed VAI. Therefore, to encourage a data driven approach to department improvement, correlations must be discovered between the VAI (and other quality metrics) and controllable inputs including, but not limited to:

- Departmental Emphases: the priorities communicated to faculty, and
- Curricula Distribution: the department specialties emphasized in the required curriculum.

Future work toward data driven university department strategies will include recording how different departments control these inputs, what settings they use, and how they influence selected quality metrics.

Acknowledgements

I would like to acknowledge Dr. Theodore Allen and Dr. R. Allen Miller of the Ohio State University Department of Industrial and Systems Engineering for their guidance. Also, I would like to thank The Ohio State College of Engineering Honors program for their support, Dr. William Rouse of the Georgia Institute of Technology and all representatives of the surveyed Industrial Engineering departments.

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